From Electrons to Neutrons – Blended Engineering Education

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Abstract
Blended instruction, a combination of face-to-face and online instruction, is a powerful instructional mode. Its power lies in the significant transfer of responsibility for learning from the instructor to the student. This represents a significant culture change for students especially for the “typical” engineering student. In this paper we share the process we followed to redesign Nuclear Phenomena for Engineering Applications (NPEA) to allow for a blended approach. We illustrate the instructional decisions that were made, their implementation, and the students’ overwhelmingly positive response to the blended environment with examples borrowed from the course itself and the data collected throughout the implementation. We discuss strategies to facilitate active participation on the discussion board in engineering classes, and share best practices to facilitate the changes in engineering students’ learning cultures necessary to transition from traditional instruction to blended instruction classes.

The course
Nuclear Phenomena for Engineering Applications (NPEA) surveys the quantitative and qualitative aspects of how atomic and nuclear phenomena apply to our everyday lives through technology and the environment. In a world that is increasingly welcoming and relying on responsible applications of nuclear technology to achieve global prosperity, the knowledge that NPEA provides can open significant career, discovery, and technology leadership opportunities. NPEA also surveys the implications of nuclear technology to instill awareness about what “responsible application” can mean.

For nuclear engineering and engineering physics majors and minors, NPEA is the first in a sequence of required courses that prepare students for a career involving nuclear technology. For the typically 20% of students who are non-majors/minors, NPEA provides the concepts and specialized vocabulary necessary to engage with the nuclear engineering and engineering physics fields. To achieve this, the course is presented in three units. I. Particle collision mechanics, special relativity, particle-wave duality, and atomic quantum mechanics. II. Nuclear structure, characteristics, and reactions: structures, forces, decay mechanics, reaction mechanics, and interaction probabilities at the nuclear level. III. Applications and implications of nuclear phenomena: radiation effects on materials and biological systems, radiation shielding, radioisotope production, radiation detection, radiation sources, fission energy, and fusion energy.

For many years, NPEA was successfully taught in the “traditional” classroom format, with the instructor lecturing his students in a large lecture hall, using technology that slowly changed with the times: the piece of chalk and the blackboard were first replaced by the overhead, then PowerPoint.

Blended learning
As technology is becoming overwhelmingly ubiquitous, so are the Internet and the Wide World Web, exploding in the classrooms of the 21st century, making “blended learning” a common form of instruction. Blended learning is a combination of face-to-face and online instruction that, when used effectively can dramatically change the learning experience of the students. By reducing "sage-on-the-stage" lecture time and shifting some of the teaching components to the online environment, more time can be spent in face-to-face class, applying course materials, often with real-world example problems that require more time to

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present and discuss than would be feasible if part of a long lecture. The balance of blending varies for every course depending on the type of course, student characteristics, and instructor background.

At most colleges and universities, engineering courses have high enrollments and are taught in traditional format with passive lectures. Unfortunately, students in high-enrollment lecture courses neither develop higher order thinking skills nor retain high-quality student-faculty interaction. Many researchers have shown the importance of interaction in education.

Blended instruction allows a course to operate 24/7, from even before the term begins to whenever the website is removed – possibly years later. As long as the server is operating and the students have electricity and internet connections, no snow day, sick day, or instructor-out-of-town day need impede the class’s progress. Interview data shows that students highly valued their ability to connect with NPEA at the time and even place of their choosing, for whatever duration they believe maximized their efficiency.

**Designing blended instruction**

So how did we take a traditional, face-to-face class and transformed it into an award-winning blended course? A brief overview of our process follows.

**Instructional Design-A Powerful Tool**

Over 100 different instructional design (ID) models try to capture or represent the ID process. Most ID models consist of five critical activities or stages that are often referred to as ADDIE—an acronym created from the name of each of the five phases: analyze, design, develop, implement, and evaluate. Although there is no such thing as an ADDIE model, the acronym has become an umbrella term often used to refer to the key processes followed by all instructional design models. Regardless of which instructional model you might choose to design your blended environment, you should go through each of the ADDIE phases.

We created the **W5h** formula as a critical component of the instructional design process:

- **Who** are my students? (freshmen, juniors, second language speakers, …)
- **What** am I teaching them? (introductory course, core subject, elective, …)
- **When** am I teaching them? (first period of the day, seminar, 3-hour class, …)
- **Where** is the class taking place (online, in a classroom, in a lab, …)
- **How** am I teaching the course? (level of blend, delivery mode, …)

And the most important of all the questions: **Why**? Why use the technology or the tool? Why teach the course? Why select this specific objective? … Trying to answer the “why?” of everything is often the most effective, albeit challenging, tool that we have when we design courses.

**The Design Brief**

At our institution, one of the most powerful tool that we use to design courses is the design brief. It is a high level design document that maintains consistency with other courses, and adherence to sound instructional design principles, and to specific instructional rules. It provides an instructional blueprint for the development and implantation of activities pertaining to the course. It is both a record of planned activities and a guide for the development and implementation of a course.

It is composed of six main areas: General information about the course, an overview, a section dedicated to the tools and technologies selected, another to the design of the user interface for the Web-based component, a third dedicated to the content and organized by unit(s) of instruction and finally a flowchart that capture visually the relationships between the various components.
From electrons to neutrons

Multiple time scales

The traditional version of NPEA operated on two time scales: the semester – divided into three equal units, with an exam after each unit; and the unit – each typically divided into nine two-hour traditional lecture/discussion classes (typically two per week) with four homework assignments due roughly every other class.

These time scales were synchronized by the standard class hour schedule (e.g., Monday and Thursday, 2-4pm). The blended version also used the semester and the unit time scales, but each unit was divided into five weeks of instruction. The “week of instruction” was a third time scale centered around one weekly required class during which the students were expected to view the assigned lecture videos as if they were actually in the classroom; at least skim the assigned reading and study the examples; take the self-assessment quiz before the beginning class; attend class, and submit the homework assigned in the previous class; complete the assigned homework assignment; actively participate in any assigned discussion forums. There was also a second optional weekly class, discussed subsequently.

Student comments early in the course showed that a few had significant difficulty adapting to this third time scale. In many engineering courses, students have the option of reading the text before or after a traditional lecture class, depending on their learning style; quizzes are something that sometimes happen at the beginning of class; homework is something to do the night before it is due. In the blended version of NPEA, students had to watch the video streams of the lectures and take a self-assessment quiz prior to class. They also had to complete their homework assignments in a timely manner so that they had time to watch the videos streams before to the next class. This represented a significant transfer of responsibility for learning from the instructor to the student. Because of this enormous culture change, allowances had to be made in the first couple of weeks until everyone could adapt.

Figures 1- a through d highlight various other temporal aspects of the course, discussed below. Figure 1-1a shows that about 45% of the students started exploring the course web site up to two days before meeting the instructor in the first class. Site tracking showed that their exploration was typically more than casual, and sometimes very wide ranging. Some of these students even found and completed the first discussion forum assignment – introducing themselves in the “Student Lounge”. During the two-hour first class, an additional 30% of students explored the site for the first time using their laptops. (As discussed subsequently, in-class observation and interviews showed that multitasking during class was popular and did not detract from learning.) There was no statistically significant association between time of first access and student performance in the course.

Figure 1-1b shows the cumulative number for course web site “hits” per student for the duration of scheduled classes. The five curves, from top to bottom, show the “maximum” student (with the most cumulative hits at a given time), the 75 percentile, the median (50 percentile), the 25 th th th percentile, and the “minimum”.
The percentile curves represent that percentile student at a moment in time, but do not represent any one student over time. The percentile curves show that, for example, by the end of the course 25% of the students (the 75 percentile and above) had about 870 or more “hits” on the site, and the median student at that time had about 670 hits. Except for the maximum, all of the curves show that site hits are proportional to the square root of time ($p < 0.0001$):

$$\text{cumulative site hits} \sim (\text{time})^{1/2}$$

This suggests that students’ site access strategies become more efficient (fewer per week) as the course goes on, but may not come to equilibrium in only 15 weeks. Since this remains the only blended instruction engineering course a Rensselaer, we could not assess how well their strategies transfer to subsequent courses. It is interesting to note that the “maximum” student quickly developed an equilibrium (linear) access strategy. Unlike other students (the percentile curves are flat during spring break and nearly flat during a non-lesson week, indicated at the top of the figure), this maximum student continued to access the course normally during these times. While the course was in session, two other students who had to go out of town for almost a week each continued to access the course normally during that time.

Figure 1-1c shows post frequency to the Anonymous Q&A discussion forum by day of week. The figure shows that, while there were more posts in the days preceding the required class when homework was due, there was significant activity throughout the week. The instructor was able to provide timely feedback and alignment at the instructor’s convenience, no matter where in the world (with internet access) the instructor was. Students taking time to answer students’ questions continued through the day before class.
Figure 1-1d takes aggregate student post data from the two days before class in Figure X-1c and breaks it down hourly. It shows bimodal posting activity peaks, at noon and 9pm. This distribution was recognized early in the course so the instructor was able to tailor site check and reply times for increased student efficiency, learning, and thus satisfaction.

Use of the discussion board

Discussion boards are an ideal medium to achieve and assess these more subjective outcomes. For example:
- discussion board participation is usually well above 70%, which is a typical threshold for verifying that an outcome has been achieved (versus in-class discussions which take more time with fewer participants);
- discussion boards allow students to “gather their thoughts”, and even facts, before making a comment (versus in-class fumbling and opinionating);
- discussion boards allow time for reflection – students reflecting for a few days on what they posted versus what their peers posted (versus what they do and don’t remember from class to class);
- instructors have a permanent and easy to review log of the discussion for assessment and their own reflection on (versus an audio or video tape of class).

A student’s success in the course meant that the student was successful in transferring responsibility for learning to himself or herself. Because the course Website presented a broad and extensive array of supplemental materials (e.g., unassigned sections of the text, in-house supplemental content, and URLs to external materials), each student learned to be selective and efficient in accessing materials that would help them understand a topic better, solve a homework problem more efficiently, satisfy their curiosity, or do none of these.

Site tracking can measure the proportion of students accessing some of these materials, giving indirect assessment of utilization (albeit with some strong confounders – consider the student who “clicks on everything”, like television channel surfing). Finally, the survey nature of the course, combined with the extensive array of supplemental materials, serves to highlight how much there is to know, while some discussion forum questions suggest that what they think they know now might change in the future, just as things changed for students on the eve of the nuclear age.

Discussion board utilization in NPEA

Three types of discussion forums were used: course management, enrichment, and mentoring. The three course management forums were the evaluation journal – a private forum for the course team to post suggestions for immediate or long-term course improvement (or just to vent), in real time and in a central archived location; the course information – to post announcements, corrections, etc. Only the course team could make original posts to this forum, but the students could reply to a post here.; and student lounge – for students to introduce themselves, contact peers (e.g., to form homework/study groups, etc.), discuss the course, vent, etc., (within the limits of proper netiquette, of course).

The weekly enrichment forums posed topical discussion questions. The discussions cover contemporary issues, investigation, and understanding and interpretation of qualitative material. Most topics require an initial post within three days of class before reading the posts from others, and then a reflective follow-up post before the next class after reading other students’ posts.

Participation was required, and the posts were quickly and somewhat generously graded for quality based on the following rubric (paraphrased from criteria developed by Professor PLACEHOLDER, From PLACEHOLDER):
- does your response make substantive and relevant points to the discussion?
• when responding to others, does your response show that you have been reading all of the responses to date?
• does your response clarify and highlight the important aspects of earlier responses and lead to a clearer statement of the discussion topic under consideration?
• does your response show evidence of analysis?
• does your response add to our understanding of the situation?
• does your response distinguish among different kinds of data (facts, opinions, beliefs, etc.)?
• does your response show a willingness to test new ideas, or are your comments “safe”?

The degree of interaction was kept small by creating group threads within a forum with about six students each: small enough to encourage a student to carefully read the other five posts in their thread in order to reflect on any themes or trends that might be observed.

The “Anonymous Q&A” discussion forum became the primary ‘meeting place’ of students on-line. Being anonymous, students felt comfortable asking any question – including questions they might be afraid were “stupid”. All students were able to benefit from these questions and answers, and could refer back to the forum throughout the course. Questions beyond the required course material were asked and answered without annoying anyone (e.g.: “will this be on the test?”).

Figure 2-3a shows the distribution of posts in the Anonymous Q&A forum. The majority of posts (60%) are student questions about the course material (25%), the instructor’s replies (27%), and other students replying (8%). The students-mentor-students percentage may seem low, but this is in part due to the large number of questions that went beyond the course material, which other students rarely ventured answers for. Table 1-1 details the distribution of posts.
Figure 2-3b shows the distribution of thread depths in the Anonymous Q&A forum. It shows that about 25% of the threads were two posts deep: ask a question, get an answer. Another 25% were four posts deep, usually the result of a follow-up question. The figure also shows that some very lengthy threads developed, sometimes as multi-student discussions with the instructor about material beyond the scope of the course.

**Correlations with Student Performance**

In this section we present some correlations between web site use and student performance as measured by each student’s final numerical grade in the course. At this time we are only exploring the correlations; in no way are we suggesting any causality. For example, while student performance correlates positively with the number of site “hits”, we are not about to suggest that students spend their time surfing the site, clicking on everything. However, if a student performs poorly on the first exam and has a relatively low site hit rate, we might first approach that student to make sure their site utilization strategy is not the problem.

Figure 3-2a shows the statistically significant (p=0.007) positive correlation (R = 23%) 2 between student performance and site hits. Observe the two highest numeric course grades: the highest grade student has by far the most hits at almost 2500, while the second highest grade has the second lowest number of hits, at less than 500 – less than the lowest grade student. Two top students, clearly with different site utilization strategies.

<table>
<thead>
<tr>
<th>Type of Post</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>professor – gives technical help</td>
<td>2.5%</td>
</tr>
<tr>
<td>professor – says you’re welcome, banter, etc.</td>
<td>1.4%</td>
</tr>
<tr>
<td>professor – other</td>
<td>3.3%</td>
</tr>
<tr>
<td>student – gives help on material</td>
<td>7.5%</td>
</tr>
<tr>
<td>student – gives help on content</td>
<td>0.3%</td>
</tr>
<tr>
<td>student – gives help on schedule</td>
<td>0.6%</td>
</tr>
<tr>
<td>developer – gives technical help</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

Table 1-1: Distribution of types of posts on the Anonymous Q&A forum.
Figure 3-2b shows the moderately significant (p=0.024) positive correlation (R = 15%) between student performance and discussion forum posts read. The discussion forum posts include those in the anonymous Q&A forum (mixed student and instructor), course information forum (mostly instructor), student lounge (student only), and weekly enrichment forums (mostly student, some instructor). These posts contain a significant amount of peer knowledge, along with some instructor alignment or affirmation. Again, observing the two highest numeric course grade students shows different peer knowledge utilization patterns.

Conclusion

Moving the lecture material online enabled a shift in responsibility for fundamental learning from the instructor to the student. The bulk of a student’s time is often spent struggling with quantitative material they are prejudiced against because of anxiety-laden names like ‘Einstein's special theory of relativity.’ Presenting the course content in a blended manner meant the student could engage with the material when they felt ready for the focus required. They took as much or as little time as they were comfortable with. This approach also allowed the instructor to concentrate on stimulating interest in applications, which best promoted student engagement with this type of content and ultimate comprehension of the fundamentals via contemporary real-world contexts.”

More specifically, the qualitative discussion forums provided both a creative and reflective outlet for students, especially those who were passionate about a topic. The passion for understanding can be infectious, and may have contributed to a high participation rate of over 75% in optional classes that explored select topics beyond the required course material. More often than not, this content was motivated by discussion threads.

The discussion forums allowed the to read, reread and reflect on the contributions that students post, make well considered corrective points where necessary and make an assessment that was at least as reasoned as their contribution. In class he would have needed a third party, most likely a teaching assistant, to perform the assessment in real time so he could properly focus on the discussion. With the blended format, that was no longer the case.”
References